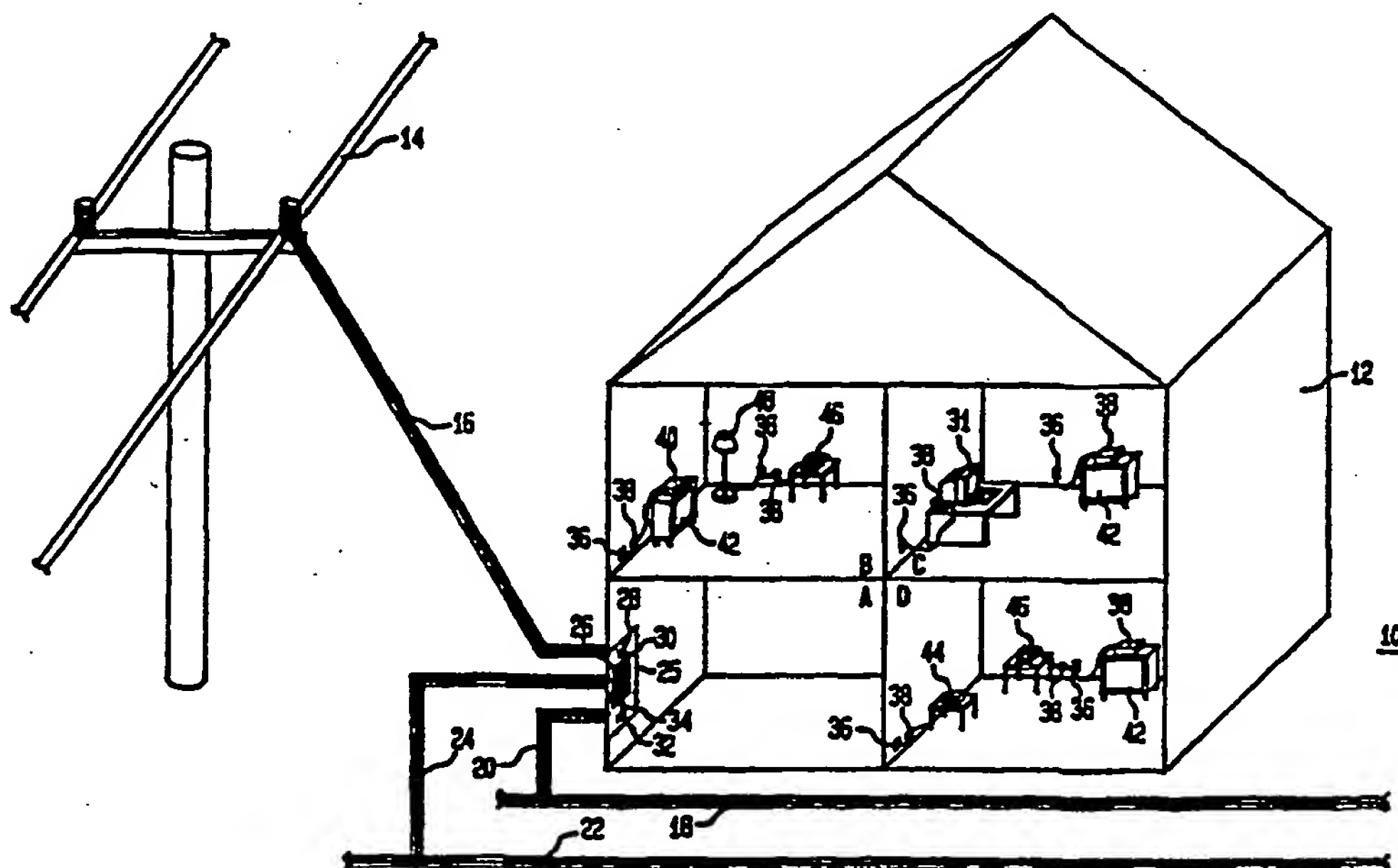


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H04B 3/54</b>	<b>A1</b>	(11) International Publication Number: <b>WO 95/19070</b> (43) International Publication Date: <b>13 July 1995 (13.07.95)</b>
(21) International Application Number: <b>PCT/US95/00354</b> (22) International Filing Date: <b>11 January 1995 (11.01.95)</b> (30) Priority Data: <b>08/180,421</b> <b>11 January 1994 (11.01.94)</b> <b>US</b> (71) Applicant (for all designated States except US): <b>ELCOM TECHNOLOGIES CORPORATION [US/US]; 78 Great Valley Parkway, Malvern, PA 19355 (US).</b> (72) Inventor; and (75) Inventor/Applicant (for US only): <b>ABRAHAM, Charles [US/US]; 804 Cheswold Court, Wayne, PA 19087 (US).</b> (74) Agents: <b>NEY, Andrew, L. et al.; 500 North Gulph Road, P.O. Box 980, Valley Forge, PA 19482 (US).</b>		(81) Designated States: <b>AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CL, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).</b>  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

(54) Title: A SYSTEM AND METHOD FOR HIGH SPEED COMMUNICATION OF VIDEO, VOICE AND ERROR-FREE DATA OVER IN-WALL WIRING



(57) Abstract

A communication network and method, including an information signal line which carries a plurality of selectable information signals. Electrical lines run throughout a building, with electrical outlets connected to the electrical line. An electrical line distribution panel connects the information signal line and the electrical line for distributing the selectable information signals over the electrical line to the location of a given electrical outlet. Dielectric-core couplers which are impedance-matched with the electrical line are connected to the electrical outlets. At least one communication station is connected to a dielectric-core coupler for receiving the selectable information signals.

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A SYSTEM AND METHOD FOR HIGH SPEED COMMUNICATION OF  
VIDEO, VOICE AND ERROR-FREE DATA OVER IN-WALL WIRING

RELATED APPLICATIONS

This application is a continuation-in-part of U.S.  
5 Serial No. 07/884,123, filed May 18, 1992 and a  
continuation-in-part of U.S. Serial No. 07/822,326, filed  
January 17, 1992, which is a continuation-in-part of U.S.  
Serial No. 07/515,578, filed April 26, 1990, which is a  
continuation-in-part of U.S. Serial No. 07/429,208, filed  
10 October 30, 1989.

FIELD OF THE INVENTION

The present invention relates to a communication  
network and method used to send and receive video, voice and  
high-speed data over conventional, existing AC wiring,  
15 telephone wiring, or coaxial wiring to communicate with  
external service systems, such as video or cable television  
systems, telephone systems and data communication systems.

BACKGROUND OF THE INVENTION

To access current communication services, for  
20 video, voice and/or data (VVD communication services), such  
as cable television and telephone services, it is often  
necessary to install separate wiring for each type of  
service. This wiring is in addition to the AC wiring used  
to distribute electrical power throughout a customer's  
25 premises. Conventional wiring used in buildings, such as  
residential homes, varies depending upon the application for  
which it is being used. Typically, cable television and  
video transmissions use coaxial cable wiring, telephones use  
bundled telephone wire and PBX telephone systems use twisted  
30 pair wiring. AC power is usually distributed over copper  
electrical wiring. Aluminum wiring has also been used for

AC power. Computer networks typically use either, or both, coaxial cable or twisted pair wiring. Some homes use antenna wire (300 ohm) for receiving television/and or radio signals. Conventional wiring can also include any other  
5 type of wiring that is used for carrying electricity for either power or electrical signal communication.

Houses and buildings (customer premises), which were not originally wired with coaxial cable for video transmission and cable television, require the addition of  
10 coaxial cabling to every room where a television set is desired. In running new coaxial cable to each of these rooms, it is often necessary to drape the cable over the outside walls of the house and then drill holes into each room to run the cable into the room. Inside the room, the  
15 cable receptacle is often placed at the entry point into the room. This avoids the cost and effort involved in pulling cable through walls. If an outlet is located away from the entry point, the cable is run along the baseboard to a desired location for the receptacle or outlet. Cable run in  
20 this manner is often unsightly and can provide a hazard if it comes loose from the baseboard.

A similar problem exists with respect to telephones when extra telephone outlets or additional lines are desired at a customer premises. With the advent of  
25 facsimile machines and computer modems, it is not uncommon to have several telephone lines running into a building, even a home. Particularly in a home situation, the number of telephone lines may exceed the number of paired wire present in the standard bundled telephone wire run to each  
30 room. Although some home telephone wiring is bundled in three pair (six wires), allowing up to three separate lines, it is more common to use wiring bundles of 2 pair wire, allowing only two separate lines at the end of a given cable run (ie. a room). A separate lines for a telephone, a  
35 facsimile machine and a computer modem requires more than the number of possible lines allowed if a home is wired with

two pair telephone line. Additional telephone lines may be necessary for use in a home office or business.

If a local area network (LAN) is desired, it is necessary to install either or both coaxial wiring and  
5 twisted pair wiring to connect the nodes of the network to the network server and/or each other node. Adding network wiring is oftentimes more expensive than adding cable television or telephone wiring. Network wiring must be  
10 installed carefully to ensure that there are no cuts or kinks in the wire which could impede data flow or integrity of the data being transmitted.

Although fiber optic cable could also be an option for VVD wiring, it is very expensive for inter home or building use. At the present time, fiber optic cabling is  
15 more commonly used in high volume VVD applications, rather than intra building applications.

In Applicant's co-pending applications, U.S. Serial Numbers 07/822,326, filed January 17, 1992 and 07/884,123, filed May 18, 1992, copies of which are attached  
20 hereto as Appendices A and B respectively and made a part hereof, there are described systems and methods for transmitting and receiving information over electrical power lines using a dielectric core coupler, such as an air-core coupler. Information signals are transmitted over the  
25 electrical power lines at the same time electricity for AC power is transmitted. The information and the electrical power are both accessible at the same time and at the same location at a customer's premises.

Systems other than those described in Applicant's  
30 copending applications use AC power lines for transmitting information signals. One of the limitations of these systems is that they do not allow high-speed data/signal communication. The approximate data flow limit of 19.2 Kbaud of line-carrier modems, for instance, would be wholly  
35 inadequate for the transmission speeds of up to 10 Mbaud, achieved by a LAN, such as an Ethernet system. The transmission of video signals typically requires

transmission rates on the order of 6 megabits per second (Mbps). Therefore video transmission can not be achieved in systems which do not allow high speed data transmission, such as systems using line-carrier modems.

5 Existing technologies for VVD communication include:

Cable Network Systems which deliver services over separately owned cable installations to set top converters and/or cable ready television set;

10 Asymmetrical Digital Subscriber Line (ADSL) technology which delivers full duplexing data, video and voice at 1.544 - 6 Mbps over twisted pair wire;

Broadband integrated Services Digital Network (B-ISDN) Synchronous Optical Network (SONET) and Asynchronous  
15 Transfer Mode (ATM) Access technologies which will initially deliver interactive video and data at a 6 Mbps data rate; and

Direct Broadcast Satellite, which requires a satellite dish at each location and then distributes television  
20 channels from a tunable receiver over coaxial line to a TV set (one receiver per television set). This technology is not data or voice oriented.

#### SUMMARY OF THE INVENTION

The present invention comprises a communication  
25 network, including an information signal line which carries a plurality of selectable information signals. Electrical lines are run throughout a building, with electrical outlets connected to the electrical line. An electrical line distribution panel connects the information signal line and  
30 the electrical line for distributing the selectable information signals over the electrical line to the location of a given electrical outlet. Dielectric-core couplers which are impedance-matched with the electrical line are connected to the electrical outlets. Finally, at least one  
35 communication station is connected to a dielectric-core coupler for receiving the selectable information signals.



In a preferred embodiment, the information signal line is a video transmission line, such as a cable television line. These lines are typically either fiber optic or coaxial cable which is tapped into at each customer premises for receiving video service. For a cable television system embodiment, the communication station includes a cable television tuner for selecting a cable television station. The distribution panel of a cable television embodiment includes a tuner capable of tuning a cable television signal from the information signal line in response to a signal from the first station.

In another embodiment of the present invention, the information signal line includes a telephone line which is tapped into at each customer premises to provide telephone service. In this embodiment, the first station is comprised of a telephone device, such as a telephone, facsimile machine, or computer. In this embodiment, the distribution panel includes a tuner for selecting the phone line for which the voice or data information will be transmitted over.

In still another embodiment, telephone service is provided directly to the electrical wiring of a customer premises without a tuner, allowing selection and "tuning" of a telephone line at the telephone location in the customer premises.

#### BRIEF DESCRIPTION OF THE FIGURES

The invention will now be described by way of non-limiting example, with reference to the attached drawings in which:

FIGURE 1 shows a communication network in accordance with the present invention installed in a customer premises;

FIGURE 2 shows several customer premises using a communication network in accordance with the present invention;

FIGURE 3 shows a block diagram of an exemplary transceiver incorporating a dielectric core coupler used in accordance with the present invention;

5       FIGURE 4 shows a diagram of an exemplary distribution panel in accordance with the present invention;

FIGURE 5 shows a frequency spectrum used in accordance with the present invention;

FIGURE 6 illustrates the frequency characteristics of the present invention used for LAN communication;

10       FIGURE 7 shows the frequency characteristics of the present invention used for video communication; and

FIGURE 8 shows phase and attenuation characteristics related to exemplary embodiments of the present invention;

15       FIGURE 9 is a flow chart of a method of selecting a channel for receipt by a communication device in accordance with the present invention.

FIGURE 10 is a schematic diagram of an exemplary coupler.

20       FIGURE 11 is a schematic diagram of an exemplary second coupler.

FIGURES 12A AND 12B illustrate the coaxially extended air-core transformer with coupling capacitor utilized in the present invention.

25                   DETAILED DESCRIPTION

There is shown in FIGURE 1 an exemplary communication network 10 operating in a house 12. Communication network 10 is constructed in accordance with the present invention. House (customer premises) 12 is  
30 shown connected to telephone line 14, video transmission line 18 (such as a cable television line) and AC power line 22. House 12 can be any building serving as a customer premises, such as an office building, storefront, residential home, etc. Telephone line 14 and video line 18



are examples of information signal lines which carry selectable information signals. Other types of information lines include those previously discussed, as well as others which carry voice, video and or data information signals.

5 It will be understood by those skilled in the art that cable television systems are a common form of video communication systems, but are not the only type of video communication systems with which the present invention may be practiced. Cable television systems are used as an example of a video  
10 communication system in this specification.

The selectable information signals on telephone line 14 are the separate telephone lines which may enter a house 12. Most homes have at least one telephone line. It is very common to have more than one telephone line to cover  
15 needs for both voice and data communication, for example. Each telephone line must be separately selectable. For home use, the selection of multiple lines is typically handled by a multiline telephone. A multiline telephone usually has several jacks, one for each line that the multiline  
20 telephone can handle. It may also have a single multiline jack, able to handle two, three or four lines, depending upon whether it accepts a two, three or four pair telephone jack. In an office setting, a telephone PBX system may handle the selection of multiple lines digitally. In either  
25 case, a physical device is used to select one or more lines (for conferencing) for operation at a particular location and time.

The selectable information signals of video line 18 are the video channels which can be individually tuned by  
30 either a video receiver. Using the example of cable television systems, the selectable information signals are the cable television channels and the video receiver is a cable-capable television set or a separate cable television tuner. It is not uncommon to have upwards of fifty  
35 selectable cable television stations accessible by a customer of a local cable television system. Recently, there has been a great deal of publicity concerning the

possibility of increasing the number of accessible cable stations to more than five hundred at a given customer premises. Each of these television stations must be capable of being separately selected. Also, some of these stations, even in present cable television systems are called "pay per view", typically requiring the customer to either order a show, movie, or other event by a personal telephone call or an automatic telephone call through the cable television tuner provided by the local cable television company.

10 In another embodiment of the present invention, video line 18 may be connected to a satellite dish (or other antenna) instead of to a local cable television system or other direct wired video service. The satellite dish would serve the same purpose as the local cable television system, namely providing access to a multitude of television channels.

Interactive television systems send signals directly over the cable to the cable television company without using the telephone lines. Interactive television would open up the possibility for communication with facilities such as libraries and schools.

Telephone line 14 is connected to house 12 via telephone tapping line 16. Video line 18 is connected to house 12 via cable tapping line 20. AC power line 22 is connected to house 12 via AC tapping line 24. Each of the three tapping lines is connected to house 12 at a distribution panel 25. ~~Distribution panel 25 consists of a circuit breaker or fuse box 26 and at least one signal selector, such as telephone signal selector 28 and video signal selector 32.~~ Circuit breaker or fuse box 26 could also include (or be substituted by) a telephone punch down block or series of coaxial cable line splitters, depending upon the particular installation and cabling over which the selectable information signals are transmitted throughout house 12.

In FIGURE 1 telephone signal selector 28 is connected to circuit breaker box 26 via connection 30.

Telephone signal selector 28 is designed to access several telephone lines and allow access to these telephone lines by devices capable of telephone line communication, such as telephones, located throughout house 12. Telephone signal selector 28 is similar in function to a multiline telephone or PBX system in selecting a telephone line(s).

Video signal selector 32 functions in a similar manner to that of telephone signal selector 28, except instead of selecting a telephone line, video signal selector 32 is designed to tune a cable television station. Video signal selector 32 is connected to circuit breaker box 26 via connection 34.

As circuit breaker box 26 is the working circuit breaker box for house 12, AC power via tapping line 24 is also connected to circuit breaker box 26. As described in Applicant's co-pending applications which are incorporated by reference, the selectable information signals used by various devices located throughout house 12 communicate over the standard AC electrical wiring (not shown) which exists in a house or building wired for AC electrical power. Both selectable information signals and AC power can be accessed at any AC outlet located in house 12. The actual wiring of a house such as house 12, is understood by those skilled in the art.

The selectable information signals and AC electrical power is shown entering house 12 in room A. Typically, these electrical lines enter a house in the basement and/or garage. Various devices using the information signal lines and power lines are shown in rooms B, C and D of house 12.

In room B, a television set 42 and ~~cable~~ television tuner 40 are shown. Although a separate cable television tuner 40 is shown, it should be understood that many cable television systems allow cable-ready televisions to operate without the need for an external tuner. Certain services, however, such as pay per view, typically require a separate cable television tuner, such as cable television

tuner 40. These special tuners are designed to communicate with the local cable television system via telephone line for pay per view programming. Cable television tuner 40 constitutes a communication station of the present invention.

Cable television tuner 40 is connected to a power line coupler modem (PLCM) 38. PLCM 38 is used to communicate selectable information signals over the electrical wiring in house 12, between a communication station such as cable tuner 40 and a signal selector such as video signal selector 32. PLCM 38 is plugged into a wall outlet 36. Wall outlet 36 is a standard AC electrical outlet in the exemplary embodiment shown. Other electrical outlets could be used, depending upon the type of electrical wiring carrying the selectable information signals.

Using 16 Quadrature Amplitude Modulation (16 QAM) and/or 16 Phase Shift Keying (PSK) modulation formats, each video channel requires approximately 1.8 MHz of bandwidth to achieve a data-flow rate of 6 Mbps. This is the data-flow rate which is necessary for video transmission. 14 channels can be selected in an exemplary embodiment of the present invention, using 1.8 MHz of bandwidth per channel (plus .2 MHz of bandwidth per channel for the channel selection control signal, equaling 2 MHz total per channel) and a frequency range of 2-30 MHz for video transmission (28 divided by 2 equals 14 channels). This requires individual communication stations to send a channel request signal to a separate tuner, such as video signal selector 32, which in turn, tunes the requested channel and transmits the selectable information signal (ie. cable television channel signal) over the electrical wiring of a building such as house 12 at the frequency of the PLCM 38 of the requesting communication station.

A 200 KHz interactive reverse channel selection band is used to send the selection signal to video signal selector 32. This channel is capable of sending a 64-128 Kbps signal to video signal selector 32.

With different modulation formats and techniques or the addition of a greater frequency spectrum, it is possible for more than 14 channels to be transmitted in accordance with the present invention. 14 channels are used  
5 as an example in the embodiments described herein.

In another embodiment of the present invention, instead of using standard AC electrical wiring, existing telephone wire could be used for the transmission of selectable information signals between television tuner 40  
10 and video signal selector 32. The present invention can use any electrical wiring for transmission of the selectable information signals. The ability to use any electrical wiring provides flexibility for users of the present communication network. A user is no longer limited to the  
15 particular outlet located in a particular position of a particular room. The user now has the flexibility to connect any sort of communication device to whatever outlet is available (AC electrical, telephone, cable, etc.) so long as the outlet in question is tied into a distribution panel  
20 such as distribution panel 25. Distribution panel 25 could have included a telephone punch-down block in place of or in addition to a circuit breaker box 26, for distributing information signals throughout house 12 using the telephone wiring. In this way, communication network 10 can be  
25 adapted to whatever wiring system is in place or which can be easily installed at a particular building or section of a building. Communication network 10 is not limited to using specific types of wiring for accessing particular communication/information services.

30 Room B of house 12 also contains a telephone 46 connected through a different PLCM 38 to a different wall outlet 36 than that used with television tuner 40. Lamp 48 illustrates the use of electrical devices in conjunction with communication devices. The selectable information  
35 signals modulated over the electrical wiring of house 12 have very high signal-to-noise ratios, as disclosed in Applicant's co-pending applications. There should be little



or no interference between devices, as all selectable information signals are transmitted over separate frequencies.

Room C of FIGURE 1 shows a computer 31 connected through still another PLCM 38 to another wall outlet 36. Although not shown, computer 31 may contain a separate modem which, in turn, is connected to the PLCM 38 shown. A PLCM 38 could also be specially designed to incorporate a modem for use with computers. An additional television set 42 is also shown in room C.

Computer 31 could be networked with other computers in house 12 (not shown), each computer connected to a separate PLCM 38 to network over the electrical wiring of house 12. In the present invention, LAN communications take place over the 120 KHz to 480 KHz frequency range, using a 6 coupler system in each PLCM 38 used for LAN communication, to achieve an effective bandwidth of 360 KHz. Each PLCM 38 used for networked computers would be tuned to transmit and receive over this frequency range.

Room D includes a facsimile machine 44 connected to another PLCM 38 plugged into another wall outlet 36. There is also shown in room D an additional television 42 and an additional telephone 46 connected at the same wall outlet 36.

Several houses 12 are shown in FIGURE 2, each connected to a video line 18, an AC power line 22 and a telephone line 14. Separate distribution panels 25 are used at each house 12. Because the present invention does not require rewiring of customer premises, existing circuit breaker/fuse boxes 26 (and/or telephone punch-down blocks) need only be connected to appropriate signal selectors 28 and/or 32 to provide interactive voice, video and data communication for customer premises.

There is shown in FIGURE 3, a block diagram of an exemplary power line coupler modem 38 used for video, voice and/or data transmission. Video and data transmission are



high speed transmissions. Video transmission requires a data flow rate of approximately 6 megabits per second (Mbps). Data transmission over a local area network (LAN) may achieve data-flow rates of 10 Mbps. As already set forth, it is possible to achieve data-flow of 6 Mbps for video signals, using a frequency bandwidth of 1.8 MHz for each video channel.

PLCM 38 shown in FIGURE 3 includes a coupler block 70. For high speed data communication, such as LAN communications, coupler block 70 is actually comprised of six dielectric-core couplers. Dielectric core couplers are disclosed in Applicant's co-pending patent applications. The dielectric-core couplers can be air-core couplers or may use another dielectric. The use of the multiple couplers within coupler block 70 allows the use of multiple modulated signals to provide the necessary data-flow rate for LAN and high speed data transmission. High speed data transmission is possible with the larger bandwidth (ie. 360 KHz) provided by the six couplers. Each coupler provides a data-flow rate of approximately fifty Kbaud. Using 6 couplers provides a combined data-flow rate of approximately 300 Kbaud. Using a Quadrature Phase Shift Keying (QPSK) modulation format achieves increases the data transmission throughput to approximately 600 Kbps. Then, using a 16 Quadrature Amplitude Modulation (16 QAM) format, the 600 Kbps rate can be doubled to 1.2 Mbps throughput.

For LAN communication at data-flow rates higher than 1.2 Mbps (ie. 10 Mbps), two or more of the video channels can be used with 16 QAM and/or 16 PSK modulation formats. Using two channels yields a bandwidth of 4 MHz in the exemplary embodiment, when only approximately 3 MHz of bandwidth is needed to achieve a throughput of 10 Mbps using 16 QAM/16 PSK modulation formats. This example illustrates another application for the high data-flow rate frequencies (2 - 30 MHz) other than for video transmission.

Like the LAN application which uses the 120 - 480 KHz frequency range, the 10 Mbps LAN application is an

inter-premises application. Computers on either LAN could, nevertheless, communicate with an information signal line outside the customer premises. One example of an outside communication for a LAN is inclusion in a Wide Area Network (WAN). Other inter-premises applications can involve intercoms (voice or video telephone) and building system monitoring. These applications can also be connected to outside information signal lines. One example is a video teleconference using several video telephones connected to an outside information signal line capable of handling video telephone information signals.

Mixer 72 mixes or divides out the sine and cosine components of the signal (I and Q components) for filtering and other signal processing. The sine and cosine components are mixed by mixer 72 if signal flow is going from the communication station to the AC wall outlet and separate the components if communication is going from the AC wall outlet to the communication station. Each of the split signals is simultaneously filtered through a separate low-pass filter 74. Low-pass filter 74 is tuned to filter out frequencies above 180 KHz for LAN/high speed data communication. Low-pass filter 74 has a cut-off frequency of 900 KHz for video transmissions.

Converter 76 converts analog signals to digital signals when receiving selectable information signals through coupler 70. For transmission in the opposite direction, converter 76 converts digital signals to analog signals. It will be understood by those skilled in the art that the present communication network can also be set up to operate in a fully digital manner. This would require each communication station to handle digital signal information.

In FIGURE 3, mixers 72, filters 74 and converters 76 are contained in a single integrated circuit chip 71.

Digital signal processor 78 provides the digital filtering as well as the 16 PSK and 16 QAM modulation/demodulation. Digital signal processor 78 is controlled by a separate microprocessor 80 which, in turn,

has separate internal or external memory 79, such as an E-PROM or EE-PROM memory. Microprocessor 80 also uses additional "glue logic" 81 for operation. Microprocessor 80 and glue logic 81 may all be located on a single integrated circuit chip. Memory 79 may also be included on this single integrated circuit chip.

Interface protocol chip 77 contains the additional communication circuitry to allow connection to a desired communication station such as cable television tuner 40. Interface protocol chip 77 provides communication protocols to transmit information to and from communication stations, such as telephones and video receivers/transmitters. Example protocols include Ethernet, Token Ring, ATM, SONET, RS-232 and others as are understood in this art.

There is shown in FIGURE 4 an exemplary embodiment of a distribution panel 25. Distribution panel 25 includes a video signal selector 32 and a telephone signal selector 28 contained in a single case unit 37.

Video signal selector 32 contains a multi-PLCM unit 33 and a multi-tuner unit 34. Multi PLCM unit 33 contains a number of PLCMs 38a - 38n, depending upon the number of accessible video channels being used. In the exemplary embodiments described above, 14 video channels can be accessed in a house 12. Accordingly, there can be up to 14 PLCMs located in multi-PLCM unit 33. Each PLCM located in multi-PLCM unit 33 is equivalent to the PLCM 38 used with the communication stations in house 12. Each PLCM 38 used in house 12 for receiving video would operate on a frequency between 2 and 30 MHz and have a corresponding PLCM in multi-PLCM unit 33. In this way, there is a one to one relationship between a PLCM used in multi-PLCM unit 33 and a PLCM (such as PLCM 38) used in house 12. PLCMs 38a - 38n can be in the form of "cards" fitted into slots (not shown) in multi-PLCM unit 33.

Each PLCM 38a - 38n is connected to a corresponding tuner 39a - 39n in multi-tuner unit 34. Each tuner 39a - 39n is capable of tuning a selectable

information signal, such as a video channel. Once a video channel is selected, the selectable signal information (the video information on the video channel) is transmitted through the corresponding PLCM in multi-PLCM unit 33, through the electrical wiring to the PLCM unit 38 in a room in house 12 and finally to the communication station (such as a cable television tuner) which requested the channel selection. Each tuner 39a - 39n is controlled through the reverse control signal transmitted in the .2MHz frequency band associated with each 1.8 MHz band for each video channel.

Telephone signal selector 28 is shown in a configuration similar to that of video signal selector 32. Telephone signal selector is comprised of a multi-PLCM unit 27 and multi-tuner unit 29. Multi-PLCM unit 27 is in turn comprised of PLCMS 38a' - 38n'. Each PLCM 38a' - 38n' is connected to a corresponding tuner 39a' - 39n'. As previously noted, for telephone service in a home, such as house 12, it may not be necessary to have a multi-tuner unit 29. Instead, all of the telephone lines would come into house 12, with each telephone line connected directly to a PLCM 38a' - 38n'. All telephone lines would then be accessible from any electrical outlet without the need to send a requesting signal. To access a line would simply require using a PLCM 38 corresponding to the PLCM 38a' - 38n' to which the telephone line is connected in telephone signal selector 28.

Telephone signal selector 28 and video signal selector 32 are shown connected to circuit breaker box 26 through connection line 30/34. Because telephone and video information is transmitted over different frequencies, it is possible to use a single connection line to circuit breaker box 26 as shown in FIGURE 4. If separate signal selectors 28 and 32 are used, then separate connection lines 30 and 34 would be used as shown in FIGURE 1.

Distribution panel 25 serves as network interface device between the information signal lines and electrical wiring on which the information signals are distributed.

There is shown in FIGURES 5, 6 and 7 illustrations of the frequency spectrum used in the present invention. LAN (high speed data) communications use the 120 KHz to 480 KHz frequency range, while video communications use the frequencies between 2 MHz and 30 MHz frequency range. Voice communication requires approximately 4 KHz of bandwidth. Therefore a sufficient number of telephone lines could be accessible between 1.7 MHz and 2MHz. Building systems shown in FIGURE 5 include HVAC, lighting, security and others which are controlled and/or monitored.

Video signals, as previously discussed, would have approximately 1.8 MHz bandwidth. A 64-128 Kbps interactive reverse control signal is interspaced at .2MHz between each of the video signals (designated F1, F2....F7) and is be used for selecting a video channel. This selection signal is transmitted to video signal selector 32 for switching to the appropriate video station. The selected video station is tuned and transmitted through the electrical wiring back to the particular video television tuner 40 which sent the selection signal. This is how a user in house 12 would select a television channel, for example.

Because of the spacing of each frequency between 2 MHz and 30 MHz, approximately 14 television stations could be tuned at any one time in a given house 12. For a multi-unit building such as an apartment building, each apartment has its own circuit breaker box and, thus, can have its own distribution panel. Each apartment, therefore, has its own 14 channel limit. Accordingly, any building or room having a separate wiring scheme (ie. distribution panel) can be provided with a selection of 14 separate television sets which can be operated simultaneously.

It is also possible, if additional television sets are used, that the telephone wiring (if present) of a house 12 could be set up as a separate distribution panel from



that used for the AC electrical wiring. This provides the typical house with a total of 28 possible televisions that can be operated at the same time.

5 An example interactive set-up for house 12 may include 4 television sets (for tuning and receiving signals only), 4 computers communicating over an outside line at high speed (thus each computer would be using one of the 14 "video" channels) and three video telephones (requiring two channels each - one channel for receiving and one channel  
10 for transmitting). A number of telephone lines may also be used, as there is enough room between the proposed range of 1.7MHz - 2 MHz for approximately 70 telephone lines (300 KHz divided by 4KHz).

15 There is shown in FIGURE 8 illustrations of the phase and attenuation of low speed signal (voice) and high speed signals (video/high speed data).

There is shown in FIGURE 9 a flowchart 82, showing steps for selecting selectable information signals (channel) in accordance with the present invention. In block 84, a  
20 desired channel is selected. This takes place at a communication station such as cable television tuner 40, for example, if the selection involves a cable television channel. This step applies equally to any selectable information signal to be selected.

25 In block 86, a control signal is transmitted through a PLCM 38, over the wiring to a signal selector, such as video signal selector 32. The particular signal selector tunes the appropriate channel corresponding to the requesting signal in block 88. The selectable information  
30 signals (ie. cable television channel signal) is then transmitted back through the electrical wiring to the PLCM 38 and finally to the communication station which requested the selectable information signal.

35 Exemplary dielectric core couplers as set forth in Applicant's co-pending application, U.S. Serial Number 07/822,326, filed January 17, 1992, are now described.



With reference next to Figs. 10 and 11, the specific circuitry for representative dielectric core couplers 92, 104 is now described in greater detail. Dielectric couplers 92 (Fig. 10), 104 (Fig. 11) each include a pair of serial LC circuits 93, 94 which resonate at the carrier frequencies FA, FB. It will be appreciated by those skilled in the art that for FSK (Frequency Shift Key) applications FA will correspond to  $F_1$  and  $F_2$  and FB will correspond to  $F_3$  and  $F_4$ . The serial LC circuit 93 shown in Fig. 10 resonates at the second carrier frequency FB, while serial LC circuit 94 resonates at the first carrier frequency FA. Similarly, the serial LC circuit 93 of Fig. 11 resonates at the first carrier frequency FA, and serial LC circuit 94 resonates at the first carrier frequency FB.

The LC circuits include respective serially and parallelly connected capacitor networks 95, 100. To each capacitor in series is connected a resistor 96 and 102 which evenly divides down the AC voltage. Preferably, the resistor values should be rated at 1 Megohm per 5 watts and the capacitors should be 200 VAC capacitors. The resistors should preferably be thick film (i.e. carbonless). The Q point of the capacitors should similarly be high. In operation, the couplers (LC) should be placed into a resin for good insulation when used with operating voltages up to 660v. At operating voltages above 660v, the capacitors should be separately placed in an oil filled insulator and the air coil transformer placed into a resin. The use of the resistors 96, 102 serve to minimize the DC current so as to prevent spiking and afford lightning protection.

It is to be appreciated that the capacitor networks 95, 100 create equivalent capacitances  $C_{eq1}$  and  $C_{eq2}$  for transmission and reception, respectively. The capacitor networks are connected to air-core transformers to be discussed below which function as the inductive element (L) of the LC circuit.  $C_{eq1}$  and  $C_{eq2}$  resonate with the primary windings of the air-core transformers.

The air coil means comprise a first air coil 97 which includes a primary winding 98 and a smaller secondary, winding 99 situated coaxially within the primary winding. The second serial LC circuit 94 includes second air coil 101 including a primary winding 103 and smaller secondary winding 104 situated coaxially within the primary winding.

The first plurality of capacitors 95 are connected together in series between one of the power-lines 91 and the primary winding 98 of the first air coil 97. The primary winding 98 of the first air coil 97 is thereafter serially connected to the other power line 91. The secondary winding 99 of the first air coil 97 is connected to its respective transmitter. The second plurality of capacitors 100 are serially connected together between one of power lines 91 and the primary winding 103 of the second air coil 101. The primary winding 103 of the second air coil 101 thereafter being serially connected to the other power line 91. As noted above, resistors 96 and 102 function to evenly divide the voltage and serve to minimize spiking and afford lightning protection.

Referring to Figs. 12A-12B, the phase shift linear air-core transformers of the present invention are described in greater detail. The novel air coil structures function as respective inductively and capacitively coupled air-core transformers for both transmission and reception. Figure 12A illustrates the transmitter transformer 97 with coupling capacitor network  $C_{eq1}$ . As shown in Fig 12A, the transmitter transformer 97 is connected in series with  $C_{eq1}$  and the power line 91. The transformer is phase shift linear and comprises a primary winding 98 and coaxial smaller secondary winding 99 which is placed between the primary winding. The primary winding 98 has a winding diameter  $2R$  39 which is greater than the diameter of the secondary winding  $2r$  41 and accordingly creates an air gap between the two. Of particular significance is the fact that both the primary and secondary windings 98, 99 in the transmitter air coils have the same number of turns

(designated by  $N_1 = N_2$ ), and are thus at a 1:1 ratio. Accordingly, the transmitter does not require a high transmission voltage, as is characterized by prior art devices. Further,  $C_{eq1}$  is set to resonate with the primary  
5 winding at the carrier frequency  $F_A$ , thus creating a band pass filter at the carrier frequency  $F_A$ . This maximizes the current at the carrier frequency  $F_A$ .

The values of  $C_{eq1}$  and the resistors, 96, 102 are set to generate a large voltage loss at frequencies less  
10 than 10KHz (thus encompassing the 60Hz and its harmonics). Thus, the significantly reduced 60Hz signal cannot generate a large enough current to pass the static capacitance. That is, for transmission, the resistivity of the primary coil is roughly equal to the lowest known value of the  
15 characteristic impedance of the power line.

The receiver transformer is now described with respect to Fig. 12B. The receiver is connected to the power line 91 via  $C_{eq2}$ . As with the transmitter of Figure 12A, the receiver air coil comprises a phase shift linear  
20 transformer having a primary winding 103 with a first diameter 2R 47 and a secondary coaxial winding 104 having a second diameter 2R 49. Accordingly, an air gap, and thus a static capacitance, is similarly created between the respective primary and secondary windings 103, 104. In the  
25 receiver transformer, the ratio of the primary and secondary windings can be about 1:1. While this ratio can be altered or modified, such a change requires a resultant alternation in the size of the air gap, i.e. the relative ratio of 2R and 2r. The capacitor network  $C_{eq2}$  is set to resonate with  
30 the primary winding at carrier frequency  $F_B$ , thus creating a band pass filter at carrier frequency  $F_B$ .

In operation, the power line voltage is significantly reduced by  $C_{eq2}$  and the resistors. Thus, the static capacitance with the secondary winding significantly  
35 attenuates the 60Hz and its harmonics, thus effectively functioning as a high pass filter. The carrier frequency voltage is thereby maximized. The air-core transformer

produces a wider phase linear bandwidth than previous systems. For good reception, the resistivity of the primary can be equal or greater than the lowest characteristic impedance of the power line.

5 From a design standpoint, the philosophy is to minimize the 60Hz line current and its harmonics at the output of the coupler. For higher voltage power-line coupling, the coupling capacitor,  $C_{eq}$ , should have a smaller value:

10  $(f)^2(\text{carrier})/(f)^2(60\text{Hz})$  ratio determines the  $V_{\text{carrier}}/V_{60\text{Hz}}$  ratio at the output of the coupler. Preferably, a higher carrier frequency should be used for higher power line voltages.  $V_{\text{carrier}}$  is measured at the preselected carrier frequency at  
15 the secondary output of the receiver coupler in volts.  $V_{60\text{Hz}}$ , measured at the same location of  $V_{\text{carrier}}$ , is the voltage of the 60Hz.

The above relationships coupled with the capacitive transformers serve to block to 60Hz current. The  
20 resistive matching serves to reduce power line noise at the bandwidth. The above makes it possible to communicate directly through power line transformers. The use of an air-core transformer reduces reflected impedances from the secondary side as well as from the power line transformer to  
25 the primary side of the air-core transformer.

The couplers of the present invention can be applied to LAN (local area network) communications and facilitate communication speeds up to 10 Kilobaud. For this application, the coupling means 92 preferably use a first  
30 carrier frequency  $F_A$  of around 75 KHz (and 81.5 KHz for FSK) and a second carrier frequency  $F_B$  of around 111 KHz (and 117.5 KHz for FSK) over power-lines 91 of up to about 1 KVAC. The coupler preferably uses first pluralities of capacitors 95, as shown therein, the coupling capacitor  
35 equivalent circuit is equal to 90 nanofarads. The first air coil 97 should have a primary winding 98 with a coil diameter of 2.2 cm, #26 gauge magnet wire and a secondary

winding 99 with a coil diameter of about 1.7 cm, #28 gauge magnet wire. The second plurality of capacitors 100 has an equivalent circuit equal to 15 nanofarads. The second plurality of capacitors 100 has an equivalent circuit equal to 15 nanofarads. The second air coil 101 should have a primary winding 103 of 2.2 cm, #30 gauge magnet wire and a secondary winding 104 with a coil diameter of about 1.7 cm, #28 gauge magnet wire. Using a suitable transistor for transmitting, the communication speed can be increased above 9.6 kbaud over power, twisted pair, and coaxial lines.

On the other side of the system, coupling means 104 comprises first plurality of capacitors 95 as shown therein, the coupling capacitor equivalent circuit is equal to 40 nanofarads (this includes the static capacitance of the air-core transformer). As above, the first air coil 97 should have a primary winding 98 with a coil diameter of 2.2 cm, #26 gauge magnet wire and a secondary winding 99 with a coil diameter of 1.7 cm, #26 gauge magnet wire. The second plurality of capacitors 100, as shown therein, coupling capacitance equivalent circuit is equal to 33 nanofarads. The second air coil 101 should similarly have a primary winding 103 of about 2.2 cm, #34 gauge magnet wire and a secondary winding 104 with a coil diameter of about 1.7 cm of the #30 gauge magnet wire.

For duplex operation, the resistive matching at the frequencies should be less than 1 Ohm for transmission and 3 Ohms for reception. For half duplex operation, the resistive matching should be about 1 Ohm for both transmission and reception.

While particular embodiments of the present invention are disclosed herein, it is not intended to limit the invention to such disclosure, and changes and modifications may be incorporated and embodied within the scope of the following claims:



What is Claimed:

1           1. A communication network comprising:  
2           an information signal line carrying a plurality of  
3           selectable information signals;  
4           electrical line, wired throughout a building;  
5           electrical outlets connected to said electrical  
6           line;  
7           an electrical line distribution panel connected to  
8           said information signal line and said electrical line for  
9           distributing said information signals over said electrical  
10          line to said electrical outlets in response to a  
11          corresponding selection signal;  
12          dielectric core couplers impedance matched with  
13          said electrical line connected to said electrical outlets;  
14          and  
15          at least one communication station connected to  
16          said air-core coupler for sending said selection signal and  
17          receiving said selectable information signals.

1           2. The communication network of claim 1 wherein  
2           said distribution panel is adapted to receive a selection  
3           signal from at least one of said communication stations to  
4           select one of said selectable information signals for  
5           transmission over said electrical line to said communication  
6           station.

1           3. The communication network of claim 1 wherein  
2           said data-flow rate of said selectable information signals  
3           over said electrical wire is substantially 6Mbps.

1           4. The communication network of claim 1 wherein  
2           said information signal line is a coaxial cable.

1           5. The communication network of claim 1 wherein  
2           said information signal line is a fiber optic cable.

1           6. The communication network of claim 1 wherein  
2           said information signal line is a twisted pair telephone  
3           line.



1           7. The communication network of claim 1 wherein  
2 said electrical line is an AC electrical wire.

1           8. The communication network of claim 1 wherein  
2 said communication station is a cable television tuner.

1           9. The communication network of claim 1 wherein  
2 said communication station is a computer with an attached  
3 modem.

1           10. The communication network of claim 1 wherein  
2 said communication station is a telephone device.

1           11. The communication network of claim 1 wherein  
2 said

3           distribution panel comprises a circuit breaker box  
4 or fuse box.

1           12. The communication network of claim 1 wherein  
2 said distribution panel comprises a transceiver adapted to  
3 distribute up to 14 separate selectable information signals  
4 throughout said building.

1           13. The communication network of claim 1 wherein  
2 said dielectric core is an air core.

1           14. A method of receiving, over an electrical  
2 line, selectable information signals carried on an  
3 information signal line comprising the steps of:

4           sending a selection signal corresponding to one of  
5 said selectable information signals through a dielectric  
6 core coupler impedance matched with said electrical line;

7           receiving said selection signal at a distribution  
8 panel connected to said information signal line;

9           interpreting said selection signal and sending  
10 said selectable information signal corresponding to said  
11 selection signal over said electrical line and through said  
12 dielectric core coupler to a receiving station.

**FIG. 1**

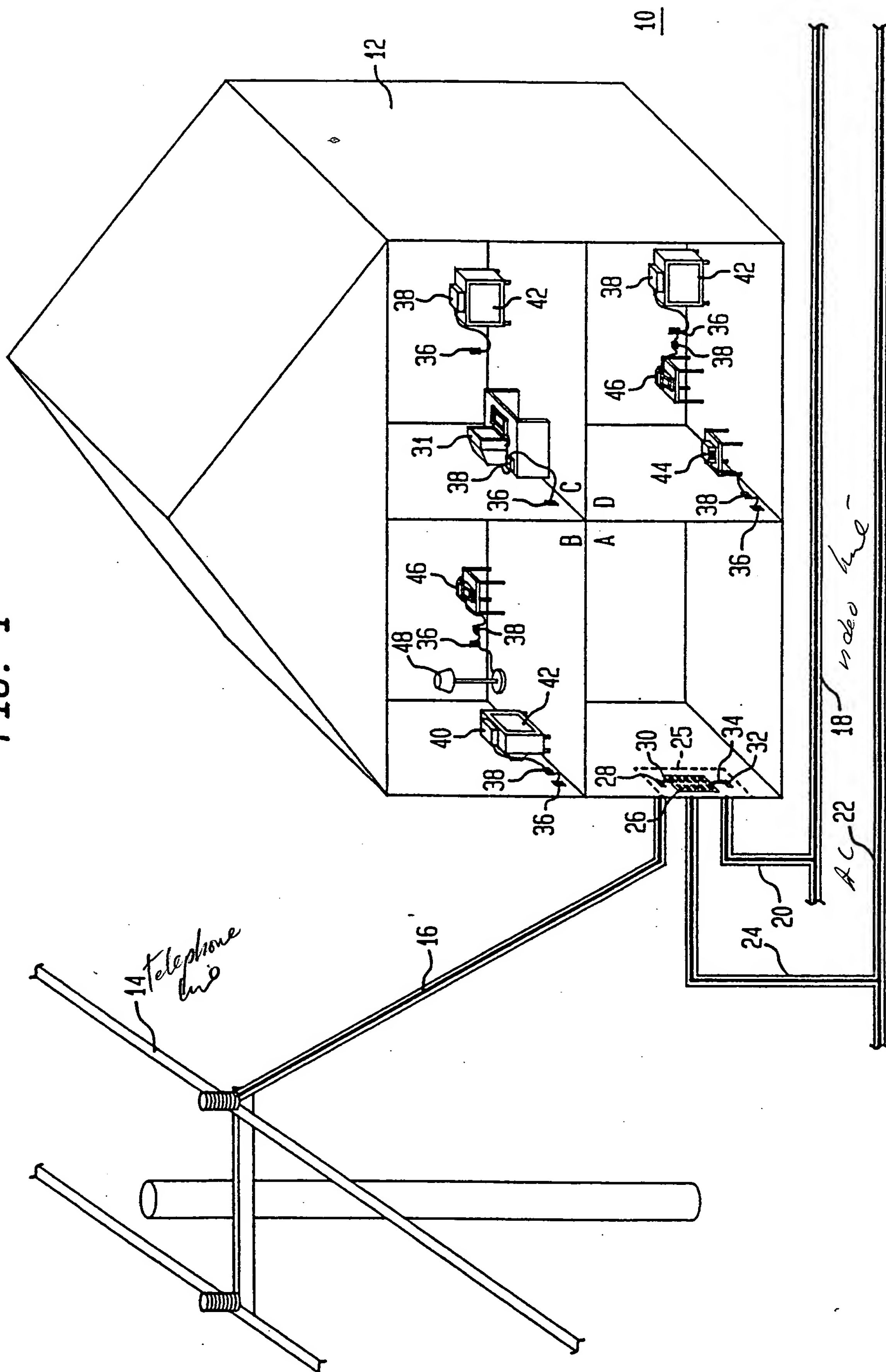
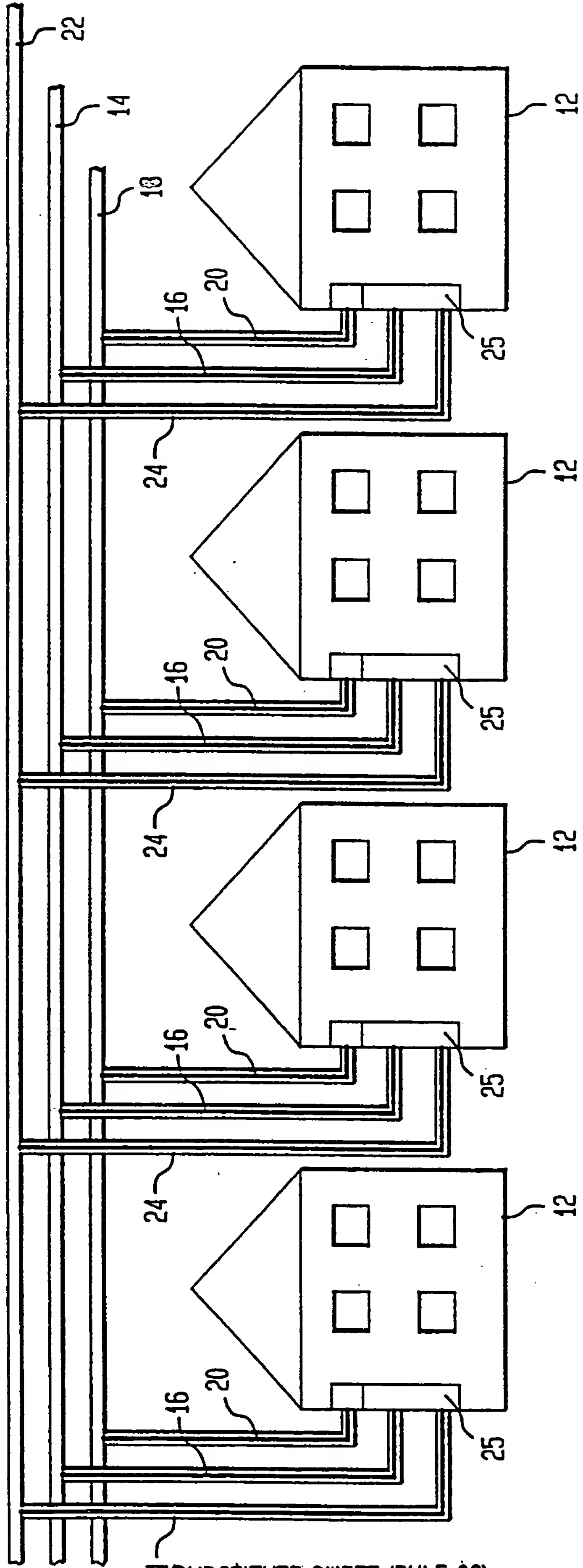


FIG. 2



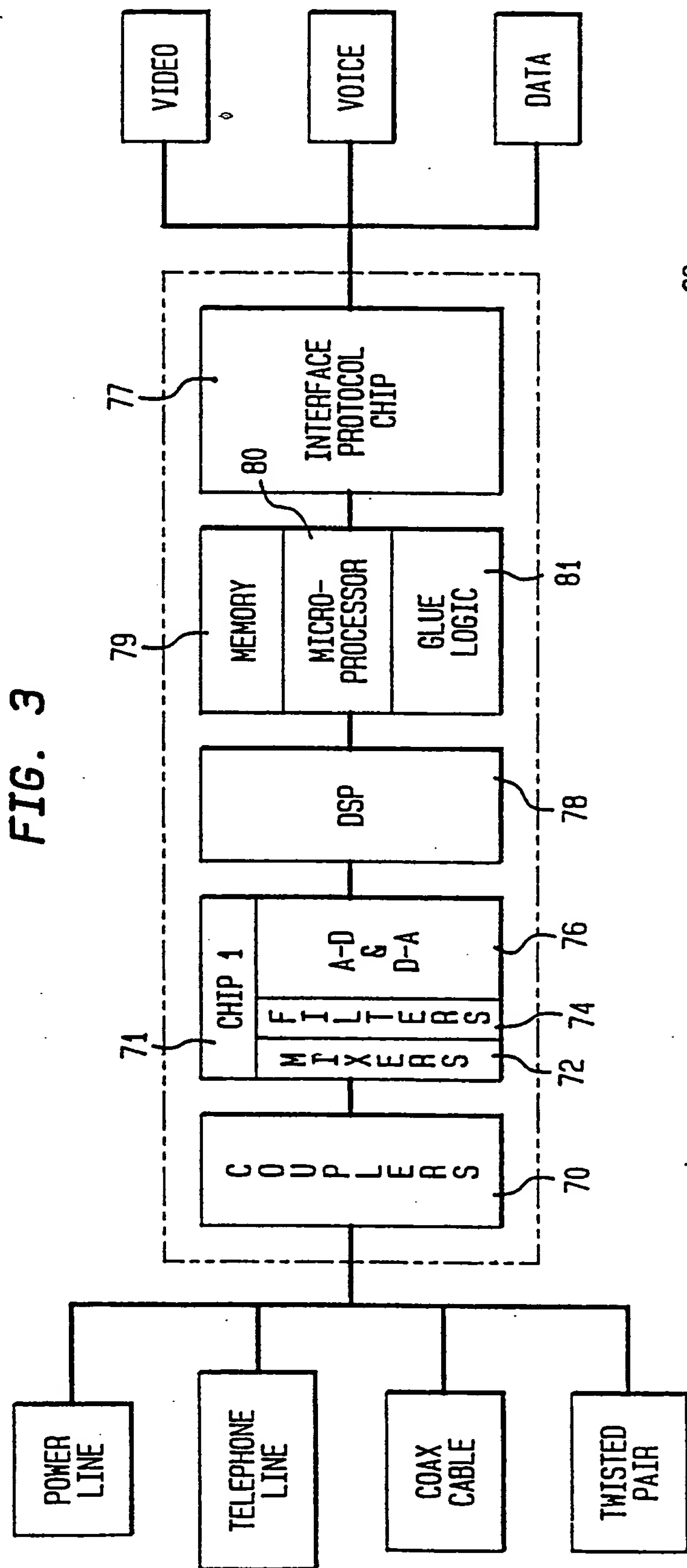


FIG. 4

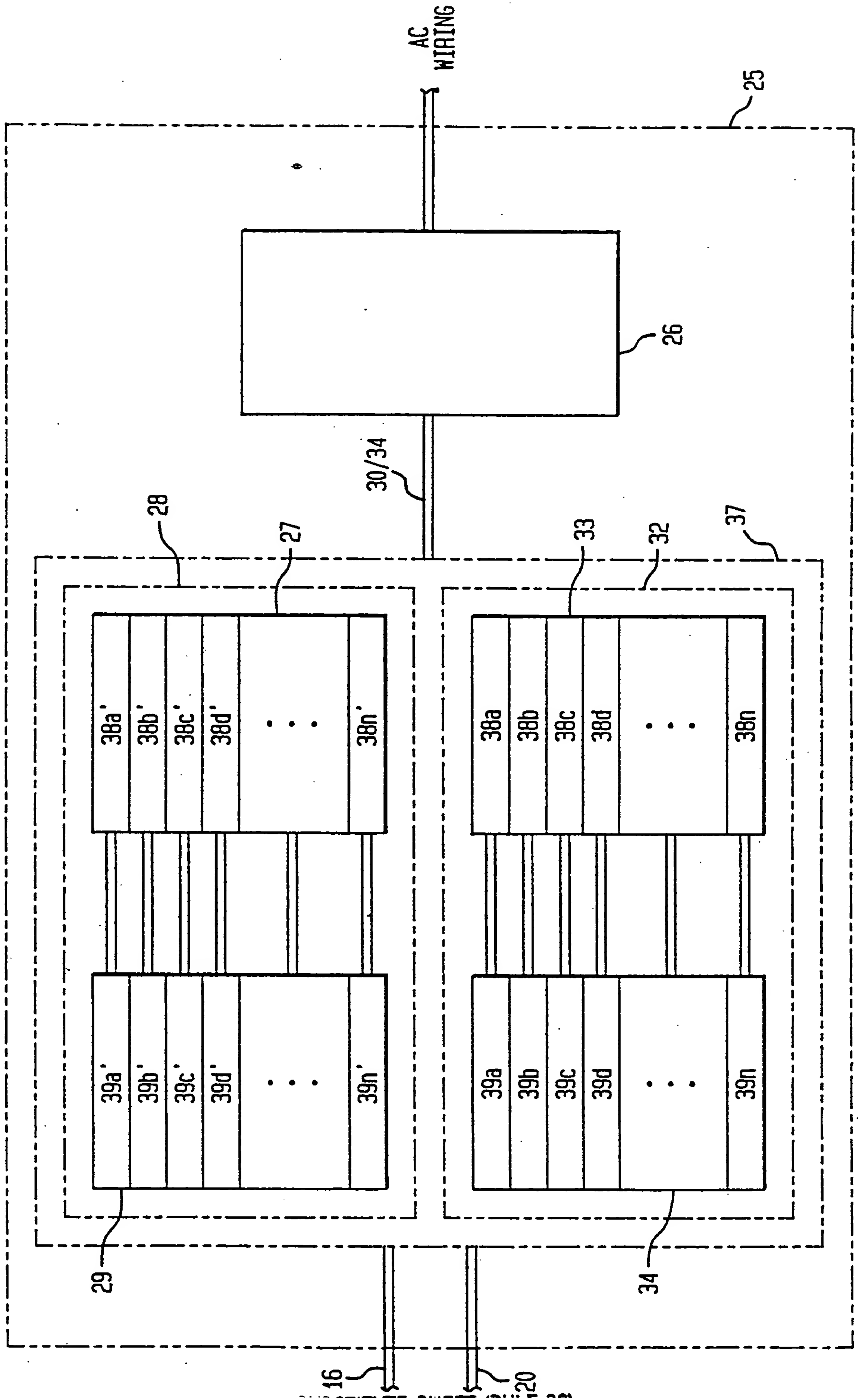


FIG. 5

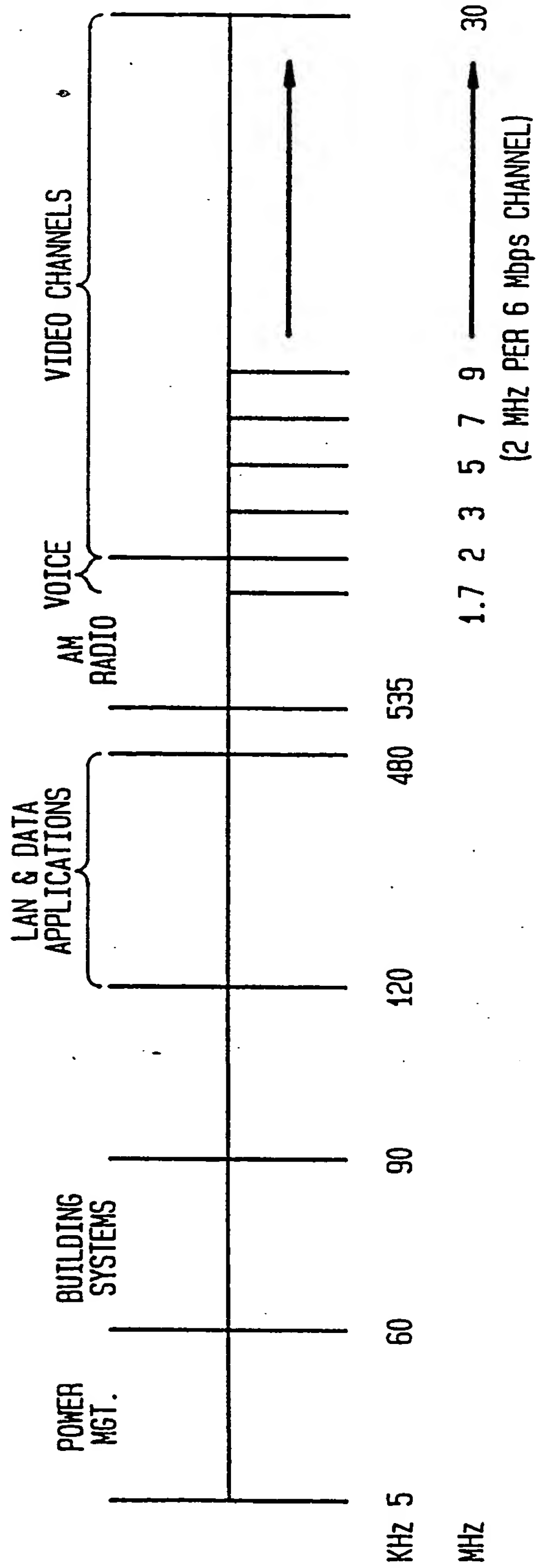




FIG. 6

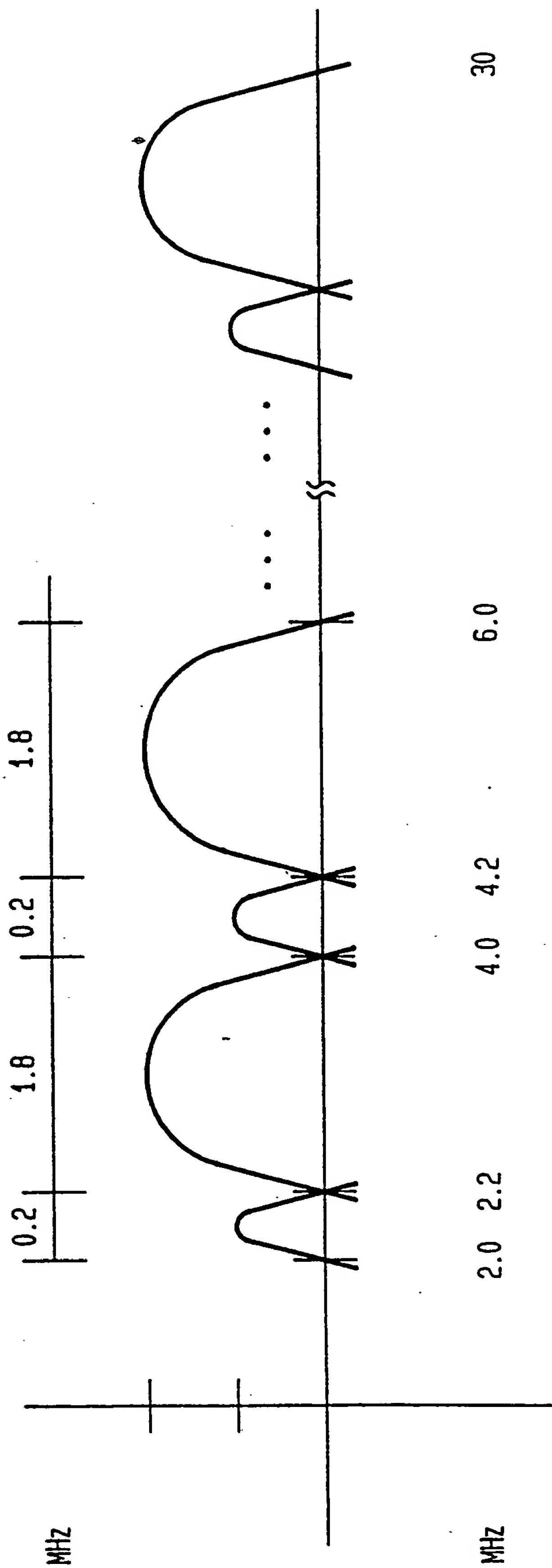


FIG. 7

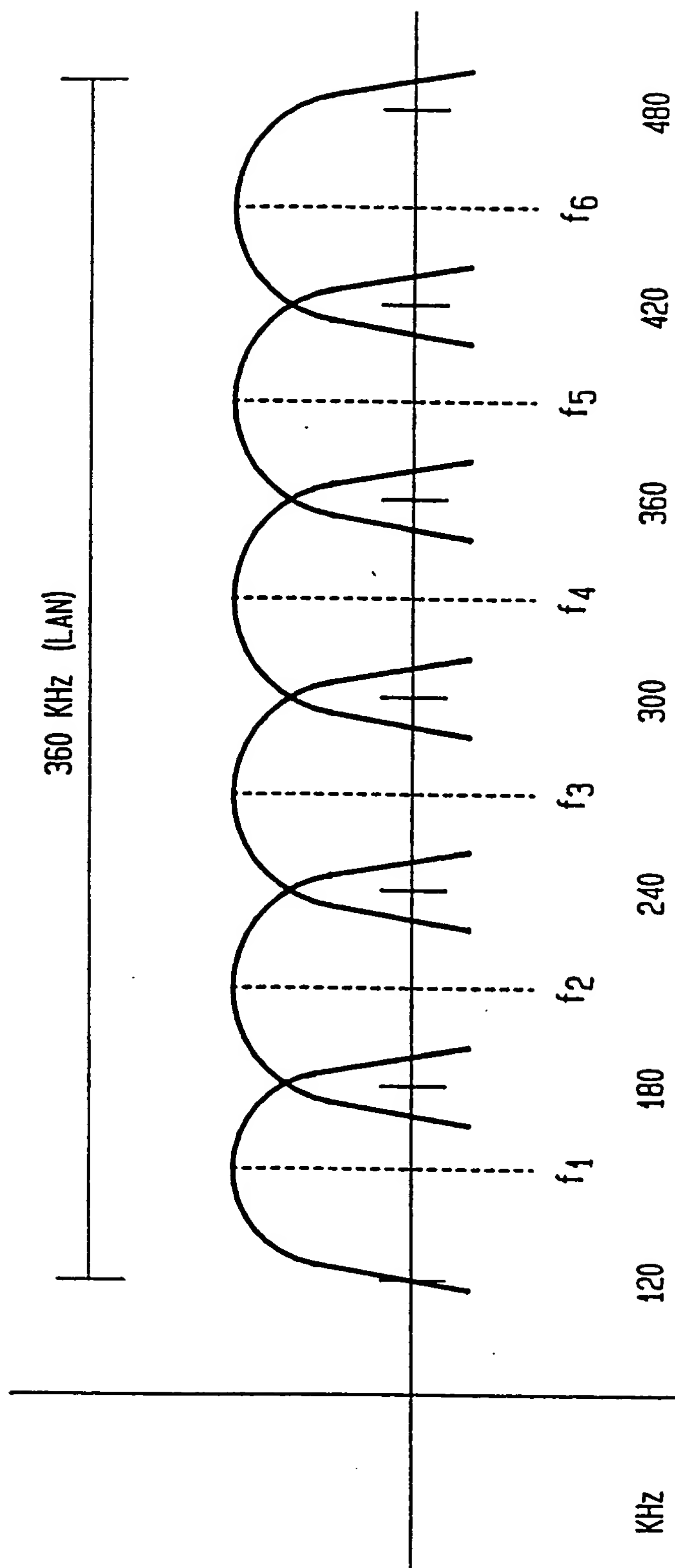


FIG. 8A

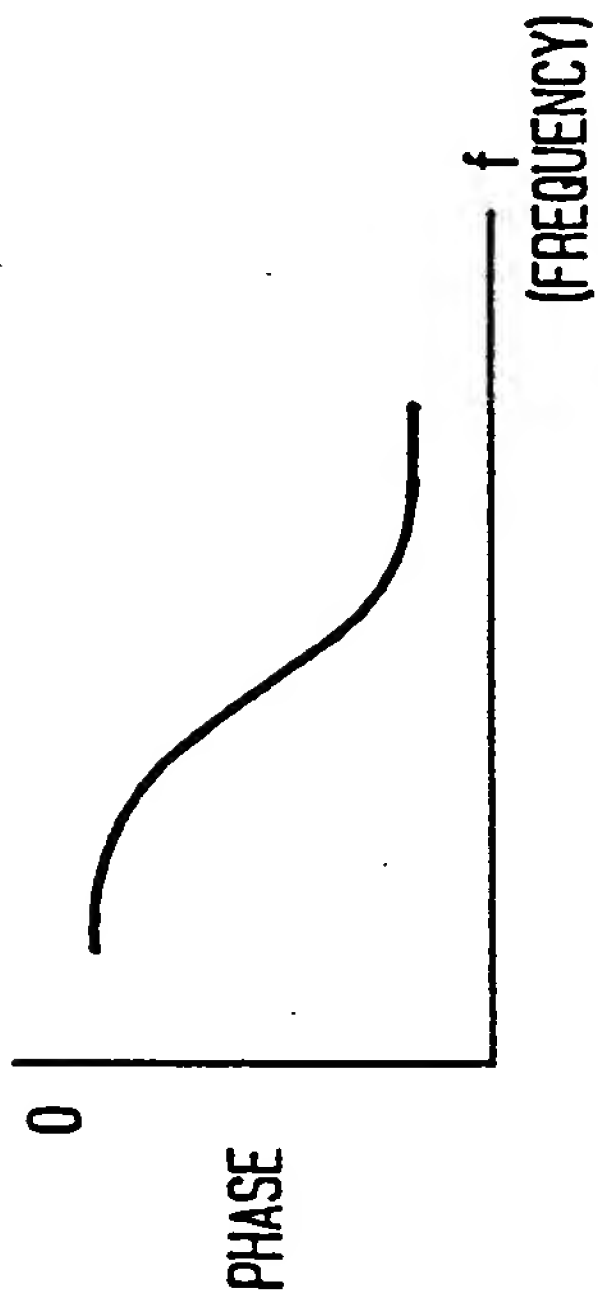


FIG. 8C

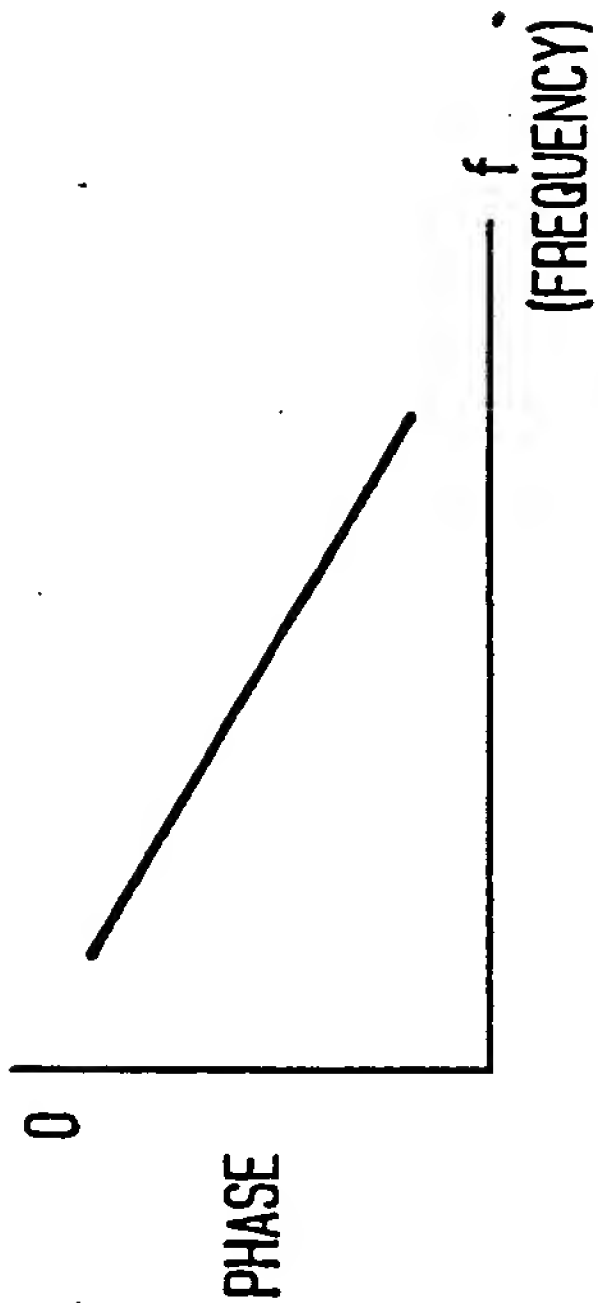


FIG. 8B

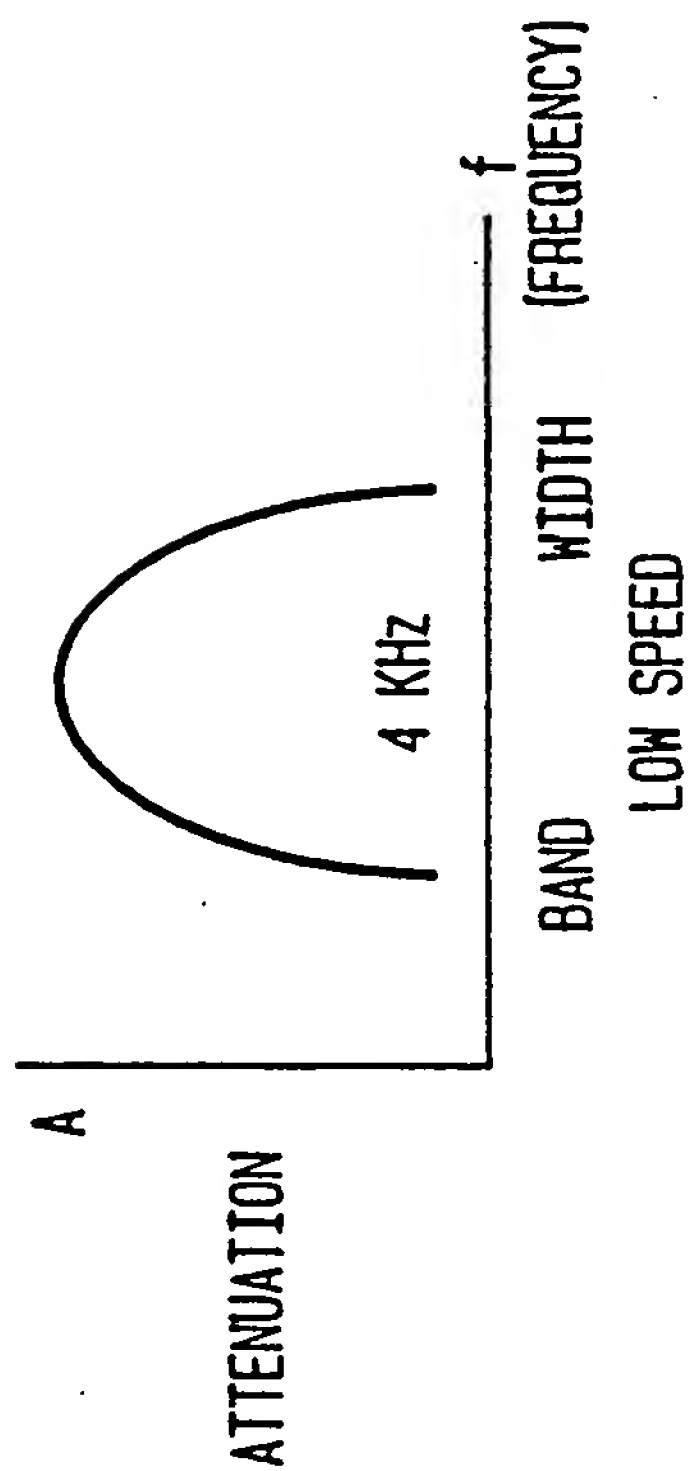


FIG. 8D

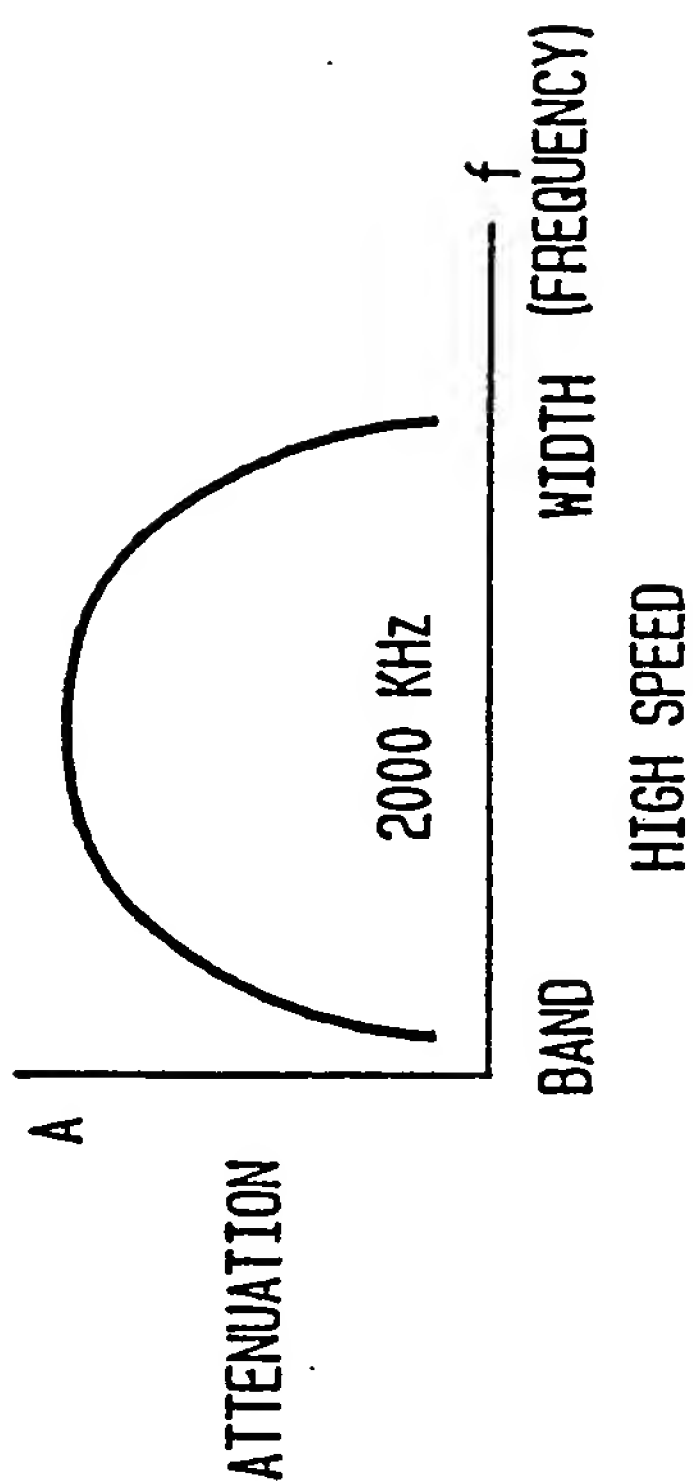


FIG. 9

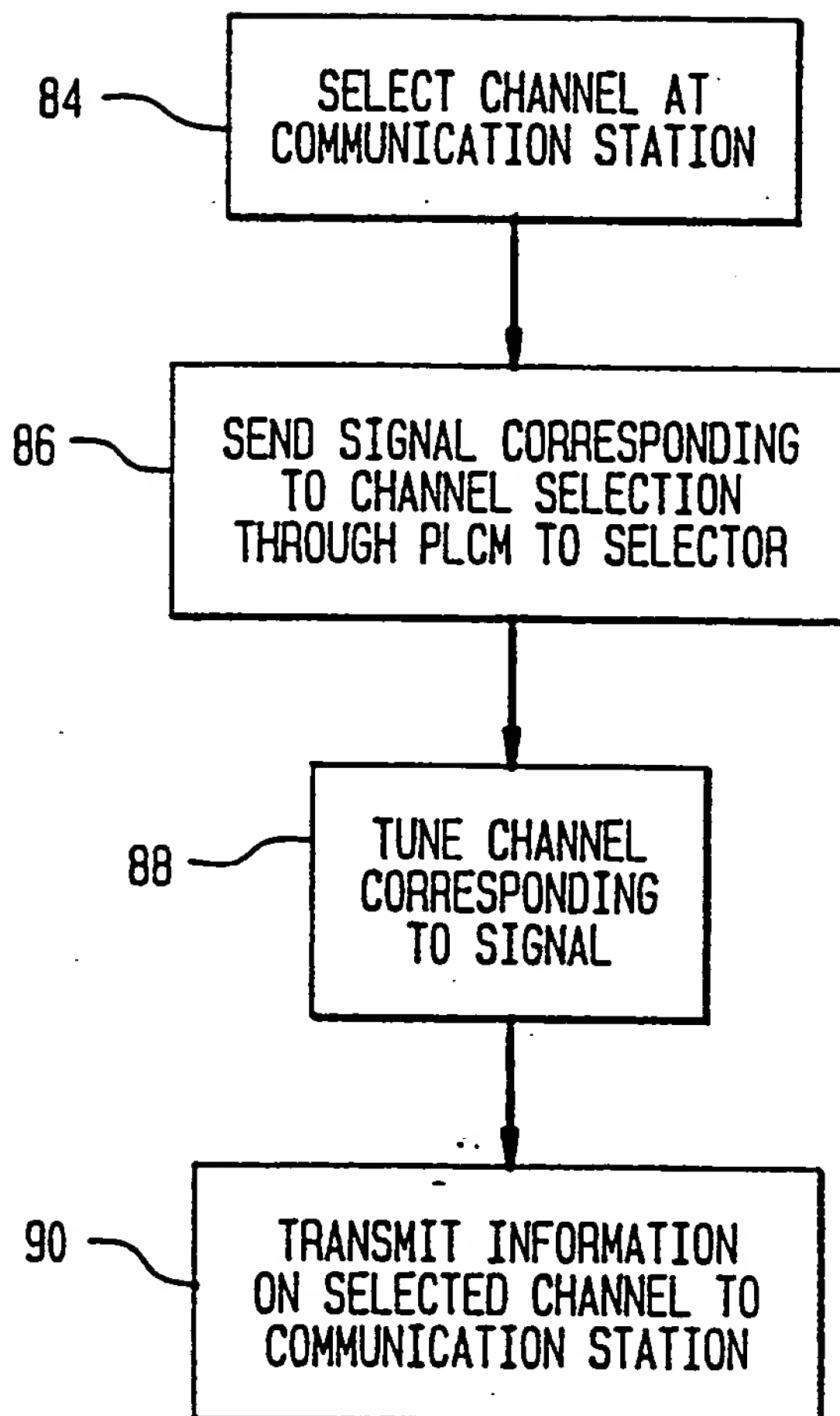
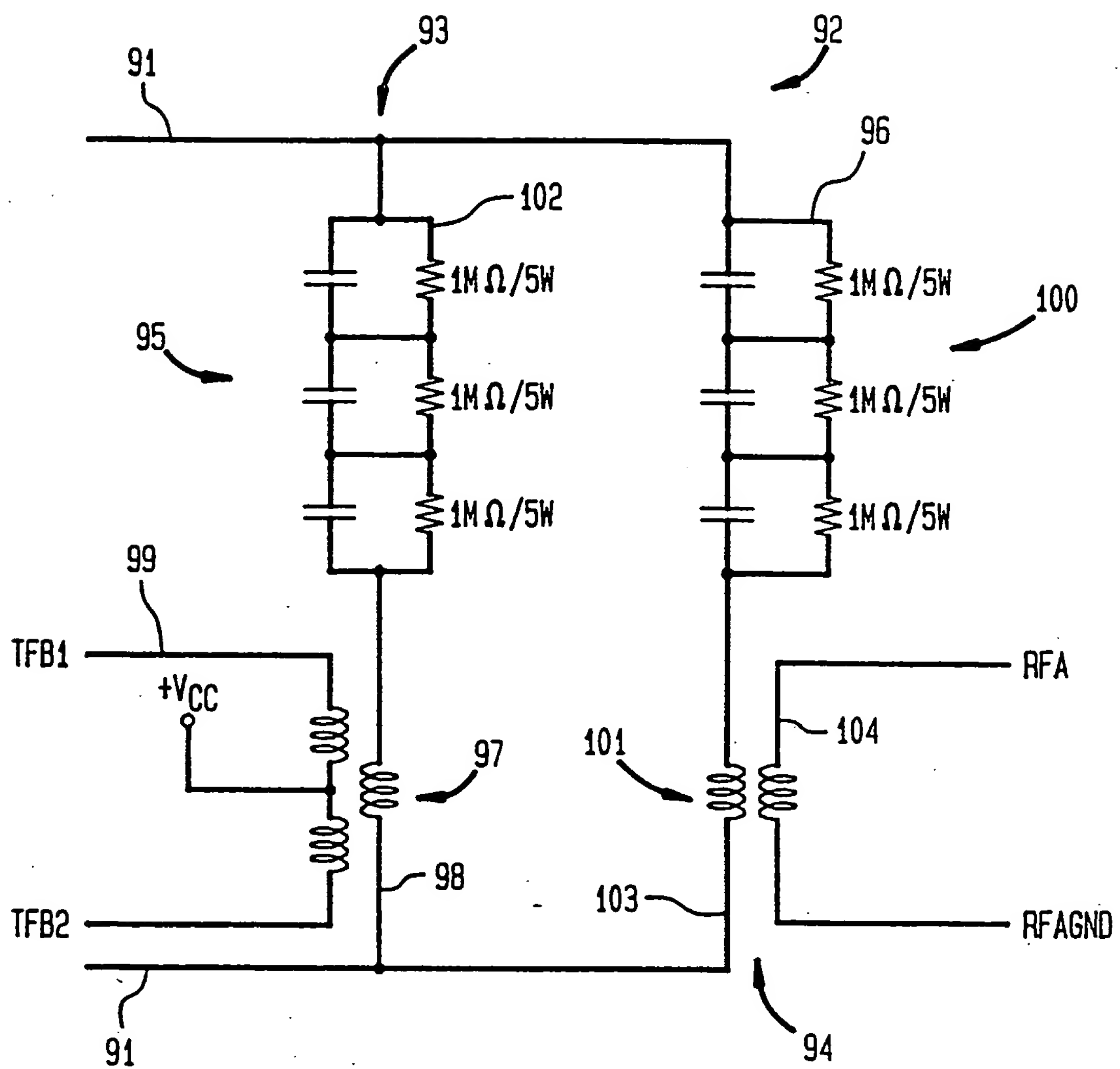


FIG. 10





**FIG. 11**

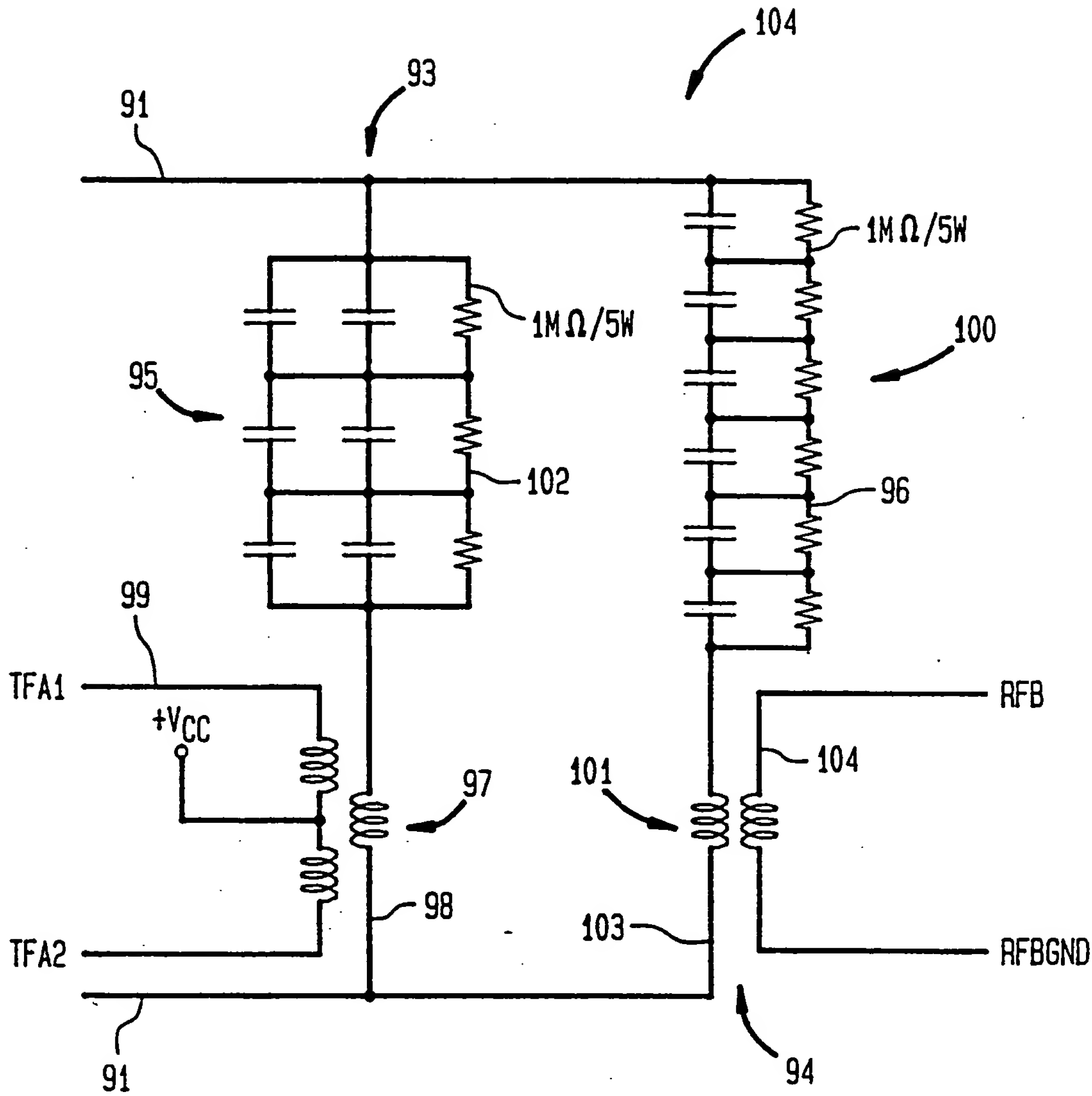
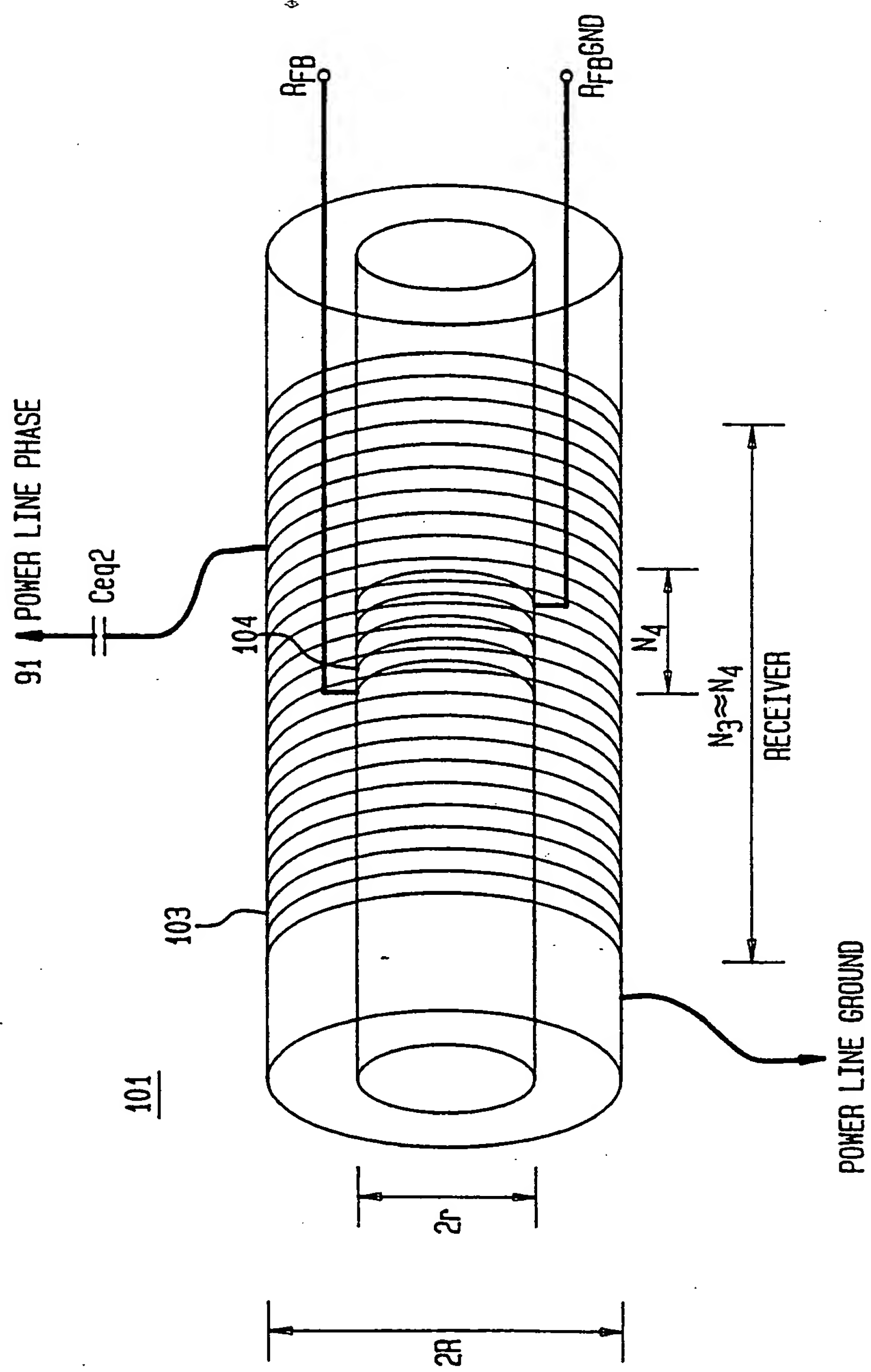




FIG. 12B



A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 H04B3/54

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO,A,90 13950 (ABRAHAM) 15 November 1990 cited in the application	1,14
A	see page 4, line 8 - line 35 see page 14, line 11 - page 15, line 2 ----	13
Y	US,A,3 943 447 (SHOMO) 9 March 1976 see column 3, line 63 - column 4, line 30 see column 5, line 35 - line 45 ----	1,14
A	FR,A,2 691 863 (KOUBI) 3 December 1993 see the whole document -----	1,7,14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

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- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search

20 April 1995

Date of mailing of the international search report

18.05.95

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Holper, G

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9013950	15-11-90	AU-A- 5644690 CA-A- 2015637 EP-A- 0470185	29-11-90 28-10-90 12-02-92
US-A-3943447	09-03-76	CA-A- 1008172	05-04-77
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